CHAPTER 5

THE INSPECTION

CHAPTER OBJECTIVES

Upon completion of this chapter, you should be able to:

1. Identify the components of a vehicle-tank meter system that are subject to inspection in the course of an official field examination.

2. Describe systematic inspection procedures for gravity- and power-operated vehicle-tank meters, based upon National Institute of Standards and Technology (NIST) Examination Procedure Outlines (EPO's), and any additional procedures required by your jurisdiction.

INTRODUCTION

What you have learned about the prominent role of vehicle-tank meters in the commercial marketplace should help you appreciate the importance of your jurisdiction's program of regular field examinations for meters currently in service. Similarly, the basic knowledge you have acquired about the design and operation of these sophisticated liquid-measuring devices should make it obvious that systematic procedures must be employed for inspecting and testing them. Given the complexity of the vehicle-tank metering system and the number of individual components that must function correctly to provide accurate and consistent measurement, a haphazard approach would at best be inefficient, requiring excessive time and effort to achieve complete and significant results, and thereby diminishing the overall effectiveness of the program. At worst, a haphazard approach could lead to overlooking or misinterpreting significant data, thereby compromising -- even invalidating -- the entire examination. In this chapter and those that follow you will receive a thorough introduction to examination procedures that employ a systematic approach to inspection and testing.

The purpose of an official weights and measures examination is to determine whether the device being examined meets requirements that are established by law or by legally mandated regulation. Thus, legal requirements form the basis of all examination procedures, and a thorough knowledge of applicable codes and administrative policies is as important a part of the inspector's job as knowing how to set up and use a field standard prover or how to conduct an accuracy test.

Most jurisdictions have adopted the comprehensive specifications, tolerances, and other technical requirements set forth in NIST Handbook 44. The requirements that apply to vehicle-tank meters are included in Sections 1.10 (General Code) and 3.31 (Vehicle-Tank Meters [VTM] Code) of the handbook. These codes will be referenced throughout the following discussions. Some jurisdictions have modified portions of these codes, and in some jurisdictions additional requirements have been imposed by State or

local laws and regulations. Your instructor will point out specific differences between Handbook 44 and the applicable codes in force in your jurisdiction and explain the significance of these differences.

Codes provide the basis for field procedures, but they are organized in a way that suits their primary function as legal documents, and as a result are often not very well suited to use in the field. Specific requirements that govern a particular component or feature of the metering system -- like the zero-setback mechanism -- sometimes appear at separate places in the codes, and some requirements are applicable to more than one element of the system. In recognition of the need for a more systematic organization of requirements, one that is suited to efficient field procedures, the NIST Office of Weights and Measures has developed Examination Procedure Outlines (EPO's) for many weighing and measuring devices, including vehicle-tank meters.

Figure 5-1 is an excerpt from the EPO for power-operated vehicle-tank meters. (Differences in design and operating characteristics necessitated the development of separate EPO's for gravity- and power-operated systems.) As you can see, the EPO provides a systematic organization, referencing the applicable paragraphs of the Handbook 44 codes for each of the major functional components of the system that are involved in measuring and indicating deliveries. As you will see in the next chapter, a subsequent portion of the EPO presents a step-by-step procedure for conducting a series of performance tests.

Because of its systematic organization, the EPO is a useful guide for the inspector in the field, and is also a tool that can be used in the course of conducting an examination; it can be used by the inspector as a checklist, to ensure that all the steps in the examination have been performed.

The EPO is intended as an outline of what should be considered a minimum examination procedure. When the inspector encounters a device that has features that are "new" to him or her, or in non-routine examinations (conducted in response to complaints, or when there is reason to suspect that the device is being used improperly or to facilitate fraud), further procedures are likely to be needed.

Complete Examination Procedure Outlines for both gravity- and power-operated vehicle-tank meters are included in Appendix A of this manual. These EPO's should be updated periodically to include changes in the codes or policies of your jurisdiction.

EPO No. 23

Examination Procedure Outline for

Vehicle-Tank Meters
Power-Operated

It is recommended that this outline be followed for all power-operated vehicle-tank meters – analog or digital. Nonretroactive requirements are followed by the applicable date in parentheses. Do not use this outline for testing milk metering systems.

Figure 5-1. Excerpts from Examination Procedure Outline (EPO) 23

H-44 General Code and Vehicle-Tank Meters Code References

1. General considerations.
   - Selection ..... G-S.3., G-UR.1.1., G-UR.1.2., G-UR.1.3.
   - Installation..... G-S.2., G-UR.2.1., G-UR.2.2., UR.1.1.
   - Position of Equipment..... G-UR.3.3.
   - Accessibility..... G-UR.2.3.
   - Assistance..... G-UR.4.4., G-UR.4.6
   - Use and maintenance.....G-UR.3.1., G-UR.4.1., G-UR.4.2., UR.2.3.

2. Marking..... G-S.1., G-UR.2.1.1., S.5.1, S.5.2.

3. Indicating and recording elements.
   - Design..... S.1.1.1.
   - Units..... S.1.1.2.(a), S.1.1.3.(b) and (c)
   - Readability..... G-S.5., G-S.6. (1/1/77), G-S.7., S.1.2., S.1.3.
   - Values of intervals..... G-S.5.3.
   - Computing-type devices
     - Display of unit price.....S.1.4.1, UR.1.2.
     - Printed ticket.....S.1.4.2., UR.2.2.
       - Exceptions for the Sale of Aviation Fuel..... UR.2.2.1.
     - Money-value computations.....S.1.4.3.

3. Indicating and recording elements (cont.).
   - Advancement and return to zero.....S.1.1.4., S.1.1.5., UR.2.1.
   - Provision for sealing..... G-S.8. (1/1/90), G-UR.4.5.

4. Measuring elements.
   - Vapor Elimination..... S.2.1.
   - Security seal on adjusting mechanism..... G-UR.4.5., S.2.2.

5. Piping.
   - Directional flow valves & discharge line and valves..S.2.3., S.3.
   - Antidrain valve.....…S.3.6.
   - Leaks..... G-UR.4.1.
   - Facilitation of fraud.....G-S.2.

An official field examination consists of four components:

- The Inspection, to determine compliance with specifications and other requirements,
- Pre-test determinations, to assure the correct application of tolerances and other test factors,
- The Test, to determine compliance with performance requirements, and
- The Evaluation of Inspection and Test results followed by approval or rejection of the device.

This division is based upon distinctions that are observed in Handbook 44 and in the EPO's. Notice that the terms "inspection," "test," "evaluation," and "examination" refer to specific and different activities (the examination comprising the other three). These distinctions will become clear as we discuss the separate components in concrete terms.

INSPECTION

The first part of the EPO is devoted to Inspection (see Figure 5-1). In the Inspection portion of the official examination, you will determine the metering system's compliance with specifications and other requirements pertaining to design, installation, and operation. The extent and emphasis of your inspection will depend on a number of factors relating to the specific device being tested and the circumstances under which it is being tested. Some of the more important factors are:

- your familiarity with the device,
- the age of the device,
- whether or not the device is of a type that has been type evaluated, and
- whether or not a complaint has been received.

Naturally, your previous experience with the particular device will affect the inspection process. If you are checking a device for the first time, you may want to perform an extensive inspection that includes a careful check of all applicable requirements in Handbook 44, including those concerned with design and installation. If you are checking a device you are familiar with, one that has been in service for some time, you may not need to spend much time on design and installation requirements; however, you will want to look for such things as fraudulent use or abuse of the equipment and inappropriate applications of the device.

The age of the device -- when it was manufactured and when it was put into commercial service -- is important because a number of requirements in Handbook 44 are nonretroactive as of a certain date. As a result, you will find that old equipment will be required to meet a different set of requirements than new equipment.

In some cases, the devices you will be testing will be of a type that has been evaluated under the National Type Evaluation Program (NTEP). NTEP is a program for determining conformance of a weighing and measuring device "type" or "model" with the relevant provisions of Handbook 44. Manufacturers voluntarily submit models of their devices for evaluation under the NTEP program. An authorized "NTEP laboratory" conducts the evaluation. When a device is found to meet all applicable technical requirements, NTEP issues a Certificate of Conformance (CC) for that device. The CC provides details of the evaluation results and device characteristics necessary for inspection and use in commerce.

Before testing a new type of device, you should determine if a model of the device has been type evaluated. If it has, you should review the device's CC to determine which features have been evaluated. Your instructor will tell you how to obtain copies of the index and of individual CCs for devices.

During the type evaluation process, extensive tests are performed in a laboratory setting to determine if a particular device model meets all applicable requirements in Handbook 44. Some of these tests are difficult to perform in the field; consequently, the existence of a CC can make your job easier -- during a field inspection, you may not need to extensively examine certain design criteria on a type evaluated device. But remember that type evaluation means that a sample of the model of the device covered by the CC has been examined, not each device; therefore, you should still review all applicable requirements when inspecting a new device. The review may simply consist of a brief visual check of an item.

Devices are designed with specific applications in mind. Some devices are designed for a narrow range of applications, whereas others have a multitude of features to satisfy many different applications. Not all features are suitable for all applications. A Certificate of Conformance will state the intended application of a device type. If you encounter a new or unusual device or feature on a device in an unusual application, it should be thoroughly tested to determine its appropriateness and to assure that it does not facilitate fraud.

Another factor that affects the nature and extent of the Inspection portion of your examination is the existence of a complaint about a particular device or the practices of a device owner or operator. You may want to perform a more extensive inspection than usual if your office has received complaints about a device or business.

As you will see in the detailed discussion that follows, most Inspection determinations are made on the basis of a careful visual examination and the inspector's experience and knowledge of the device. This does not mean, however, that the Inspection may be approached casually, or that compliance with any requirement can be taken for granted just because the device has received type approval. It is not at all uncommon to discover non-compliance in a number of areas covered in the Inspection, especially when the equipment is old or has not been properly maintained.

Furthermore, it is much more likely that modifications intended to facilitate fraud will show up in the course of a careful inspection than in performance tests.

You should also keep in mind that your inspection is not limited to visual means or any other. It is the inspector's responsibility to decide what is necessary to determine the compliance status of the device. If you have reason to believe that a correct determination requires additional testing, either in the field or under more controlled conditions, you should consult your supervisor so that appropriate arrangements can

be made. However, the cost of additional testing to the owner or operator of the equipment, including the cost of lost productivity while it is out of service, must not constitute an unreasonable burden. The decision to conduct additional testing will generally involve weighing the probability that a suspected violation will be confirmed against the cost of testing -- including the cost to the jurisdiction. So you should be prepared to explain and justify your recommendation.

The remaining sections of this chapter will present the Inspection for vehicle-tank meters. Each of the items included in the EPO's will be discussed in detail. However, in the interest of providing a basic framework for field procedures, we will begin with the General Considerations and Marking sections of the EPO, and some of the sub-headings will be presented in a modified order. (The Inspection portion of the EPO's for gravity- and power-operated vehicle-tank meters are identical; specific differences in procedure will be pointed out as we proceed.)

GENERAL CONSIDERATIONS

The items under this heading refer, for the most part, to requirements and specifications from the General Code that are necessarily broad and comprehensive in nature. They may also relate specifically to items covered elsewhere in the Inspection or Test portions of the examination. They are nonetheless important, and should not be ignored simply because they are general. On the contrary, the inspector should keep these general considerations in mind throughout the examination.

Accessibility

All elements of the system that are subject to inspection and testing must be accessible to the weights and measures inspector and to any required test equipment. For vehicle-tank meters, these elements include:

- all indicating and recording elements (register, ticket printer, totalizers, etc.)
- the meter and air eliminator, including the air vent lines for the air eliminator
- all piping between the tank compartment outlets and the discharge nozzle, and all automatic and manual controls
- tank compartment fill openings

If access to these elements is not immediately available at the time of the examination, it is the responsibility of the owner or operator to make them accessible.

G-UR.2.3. Accessibility for Inspection, Testing, and Sealing Purposes. - A device shall be located, or such facilities for normal access thereto shall be provided, to permit:

(a) inspecting and testing the device;

(b) inspecting and applying security seals to the device; and

(c) readily bringing the testing equipment of the weights and measures official to the device by customary means and in the amount and size deemed necessary by such official for the proper conduct of the test.

Otherwise, it shall be the responsibility of the device owner or operator to supply such special facilities, including necessary labor as may be needed to inspect, test, and seal the device, and to transport the testing equipment to and from the device, as required by the weights and measures official.
(Amended 1991)

In general, accessibility is not a problem for vehicle-tank meters, since the vehicle can readily be moved to a more suitable position, for example, to provide sufficient room for the prover. However, if the meter is installed in a locked cabinet, the operator must provide a key. In addition, any housing or cabinetry that encloses the piping to protect it from exposure to the elements must either be readily removable, or must be removed ahead of time so that the entire system can be inspected.

Assistance

Several steps in the examination procedures require two people to perform them safely and accurately. For example, assistance is usually required to position the vehicle correctly in relation to the prover, whether it is mounted above ground or in a pit. And when product is pumped from the prover back into tank compartments at the conclusion of a test, it is often necessary for an assistant to hold the return hose outlet securely at the tank fill pipe to prevent accidental spillage while the inspector operates the pump, observes the correct drain time, operates the prover drain valve, and disconnects the return hose from the prover.

It is also good practice (and a matter of policy in many jurisdictions) to have an experienced employee operate the metering system, while the inspector operates only the test equipment.

Most weights and measures jurisdictions assign only one inspector to a field examination, and where assistance is required, the inspector must not attempt to perform these steps alone. The General Code requires that in situations like this an assistant must be provided by the owner or operator of the device.

G-UR.4.4. Assistance in Testing Operations. - If the design, construction, or location of any device is such as to require a testing procedure involving special equipment or accessories or an abnormal amount of labor, such equipment, accessories, and labor shall be supplied by the owner or operator of the device as required by the weights and measures official.

It is obviously important that the owner or operator be notified of the need for assistance far enough in advance to allow him or her to make adequate provision. Your jurisdiction may have specific policies and procedures regarding assistance. Your instructor will explain them to you.

G-UR.4.6. Testing Devices at a Central Location. -
(a) When devices in commercial service require special test facilities, or must be removed from service for testing, or are routinely transported for the purpose of use (e.g., vehicle-mounted devices and devices used in multiple locations), the official with statutory authority may require that the devices be brought to a central location for testing. The dealer or owner of these devices shall provide transportation of the devices to and from the test location. (Added 1994)

It is equally important to provide the owner or operator sufficient notice when scheduling the testing of devices at special test facilities at a central location.

Selection

As you know, vehicle-tank meters are available in a great variety of designs to meet the needs of specific commercial applications. A number of usage factors are considered by the owner or operator in selecting the right equipment, including the physical and chemical properties of the product(s) to be dispensed and the expected range of operating conditions. For example, it is usually necessary for metering systems that handle corrosives to be made of special materials like stainless steel that will not react chemically with the product. Similarly, highly viscous products, such as asphalt emulsions, generally require meters designed for relatively high working pressures to compensate for pressure drop, especially at higher flow rates. Such products may also have to be handled at higher temperatures, which requires special design features. Or a single meter may have to make some deliveries that require relatively high discharge pressure to elevate the product to the delivery point, but other deliveries that require relatively low discharge pressure, so it will have to be designed to be accurate at either end of a range of operating conditions.

Using equipment whose design is not suitable for its application is never good practice, and will generally be more costly for the owner or operator in the long run, since components will wear more rapidly and are more likely to malfunction. But where weighing and measuring devices are concerned, the use of unsuitable equipment can also affect the accuracy of the device (as, for example, when flow rates outside the rated range of the meter must be used to develop required discharge pressure), and it is for this reason that the selection of the equipment is covered in the General Code.

G-UR.1.1. Suitability of Equipment. - Commercial equipment shall be suitable for the service in which it is used with respect to elements of its design, including but not limited

to its weighing capacity (for weighing devices), its computing capability (for computing devices), its rate of flow (for liquid-measuring devices), the character, number, size, and location of its indicating or recording elements, and the value of its smallest unit and unit prices. (Amended 1974)

G-UR.1.3. Liquid-Measuring Devices. - To be suitable for its application, the minimum delivery for liquid-measuring devices shall be no less than 100 divisions, except that the minimum delivery for retail analog devices shall be no less than 10 divisions. Maximum division values and tolerances are stated in the specific codes.
(Added 1995)

Several of the specifications covered elsewhere in the Inspection relate to the suitability of the device in regard to particular elements, but it is important -- and most efficient -- to make a general assessment of the suitability of the equipment at the beginning of the examination.

Specific items of information, including maximum and minimum flow rates and use limitations, are required to be marked permanently on the device (see section on Marking later in this chapter for details). The operator's manual and/or instructions for installation that come with the meter from the manufacturer or distributor usually include a discussion of appropriate applications and will also mention specific applications that are not appropriate. If these sources are not available, or do not provide enough information to make a determination, the local distributor of the equipment, sales representative, or authorized repair service can usually answer any questions you have.

The General Code includes a specific paragraph, G-UR.1.3., to address suitability requirements for liquid-measuring devices. This paragraph specifies that the minimum delivery be no less that 10 divisions for retail analog devices and no less than 100 divisions for other liquid-measuring devices.

Of course, you will have to rely on the owner or operator to describe to you how the equipment is actually used. If you have reason to doubt the accuracy of this information, check with your supervisor about making further inquiries. You may also ask to see copies of actual delivery tickets to verify compliance with suitability and use requirements.

One specific item is covered under this heading in the EPO. This requirement establishes an upper limit for the value of the smallest unit of delivery indicated or recorded by the equipment.

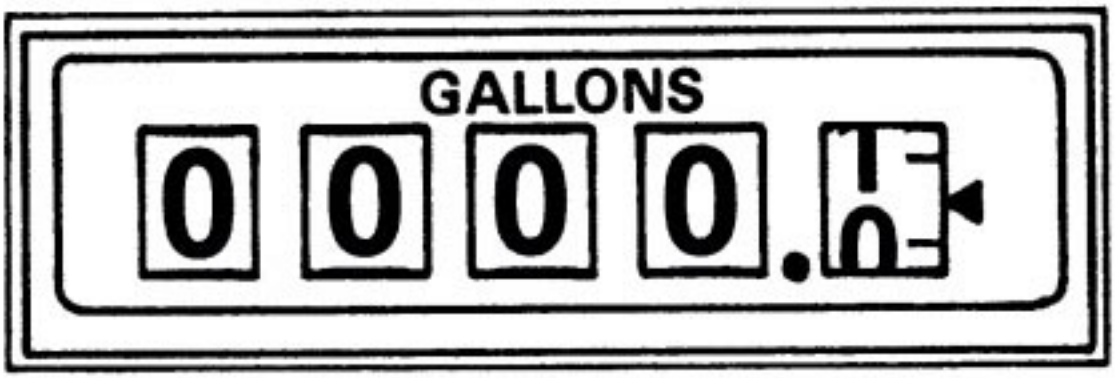
S.1.1.3. Value of Smallest Unit. - The value of the smallest unit of indicated delivery, and recorded delivery if the meter is equipped to record, shall not exceed the equivalent of:

(a) 0.5 L (0.1 gal) or 0.5 kg (1 lb) on milk-metering systems

(b) 0.5 L (0.1 gal) on meters with a rated maximum flow rate of 500 L/min (100 gal/min) or less used for retail deliveries of liquid fuel, or

(c) 5 L (1 gal) on other meters.
(Amended 1989, 1994)

The requirement for a smaller unit (0.1 gal or less) for milk-metering systems and on meters used for retail deliveries of liquid fuel relates to the manner in which these products are usually metered. Milk tankers are usually used to pick up milk from individual farmers and bring it to a dairy. In order to reduce waste, and to assure that a delivery lot will be uniformly fresh, the truck will pick up all the milk that is available at each stop. It is, of course, highly likely that this amount will be a certain number of gallons plus a fraction of a gallon. Some farmers also deliver from more than one storage tank. Requiring the smaller unit of delivery thus assures that the seller (the farmer) will be credited for all milk to the nearest 0.1 gal. The same rationale applies to home heating fuel, which is often delivered to "top off" the receiving tank, that is, until the tank is full. Again, the amount actually delivered will almost always include a fraction of a gallon. In this case, the limitation protects the buyer from the practice of rounding a fractional amount to the next highest gallon. For many other liquid products, the amount of a delivery is determined beforehand, and will usually not be in units of less than a gallon. (Note that meters may indicate and/or record smaller units than those specified, and many of them do.)



In the case of an analog register, the smallest unit indicated is the value of the smallest graduated interval. In this example, the smallest unit indicated is 0.1 gallon (0.8 pint).

Figure 5-2. Smallest Unit Indicated

A detailed procedure for inspecting indicating and recording elements covered later includes this requirement as well. At this stage of the Inspection, it is sufficient to check the smallest units on the main indicator that is mounted either on the meter itself or in the truck cab. Any meter that indicates tenths of gallons (like the one shown in Figure 5-2) will meet this requirement, regardless of the product dispensed.

Installation

Even a meter that is suitable for its application may not perform accurately and consistently if it is not installed properly. For example, the use of piping or connectors with dimensions other than those specified by the manufacturer can affect various operating characteristics of the meter, including working pressure and flow rates, and these, as you know, can affect the accuracy of the meter.

Proper installation also involves considerations of safety, security, accessibility, and environmental factors (such as air quality and pollution, as well as the effects of weather, accidental collision, and radio frequency and electromagnetic interference on the device). For these reasons, the General Code requires that the manufacturer's instructions be followed in installing the meter and accessory equipment as a means of assuring that the device performs as it is supposed to.

> **G-UR.2.1. Installation.** - A device shall be installed in accordance with the manufacturer's instructions, including any instructions marked on the device. A device installed in a fixed location shall be so installed that neither its operation nor its performance will be adversely affected by any characteristic of the foundation, supports, or any other detail of the installation.

It is neither practical nor, generally, necessary to check each item in the manufacturer's instructions. You should at least, however, determine by visual inspection whether the meter is securely mounted and, if it has electrical components, whether there is any exposed wiring. As you proceed through the examination, results from inspecting and testing particular elements may lead you to the conclusion that a substandard condition was the result of improper installation.

You should, however, check one specific item that is included in the EPO under this heading. It relates to the requirement that some means be provided to prevent operation of the device at a discharge rate in excess of the rated maximum.

> **UR.1.1. Discharge Rate**. - A meter shall be so installed that the actual maximum discharge rate will not exceed the rated maximum discharge rate. If necessary, means for flow regulation shall be incorporated in the installation, in which case this shall be fully effective and automatic in operation.

In many systems, the maximum discharge rate is effectively limited by factors such as the inside diameter of the piping and the pressure developed by gravity or by a pump (in the case of power-operated systems). However, in some systems additional means of controlling flow are necessary. This is often accomplished by a pilot-operated control valve, which is actuated either electrically or mechanically in response to a sensor located on the discharge side of the meter. The operation of such flow control valves need not concern us here. What is important in regard to the requirement is that such a device is automatic, that is, that it shuts off flow when the maximum discharge rate is exceeded without any action on the part of the operator. On the other hand, a system incorporating a flow rate indicator and manual throttling valve as its means of preventing an excessive discharge rate would not meet this requirement, since this would not be an automatic means (even though such mechanisms are appropriate for controlling flow within the rated range, and are not prohibited).

Use and Maintenance

A precision measuring device can be expected to perform accurately and reliably only if it is used and maintained properly. Two paragraphs of the General Code establish correct use and maintenance as a requirement.

G-UR.3.1. Method of Operation. - Equipment shall be operated only in the manner that is obviously indicated by its construction or that is indicated by instructions on the equipment.

G-UR.4.1. Maintenance of Equipment. - All equipment in service and all mechanisms and devices attached thereto or used in connection therewith shall be continuously maintained in proper operating condition throughout the period of such service. Equipment in service at a single place of business found to be in error predominantly in a direction favorable to the device user shall not be considered "maintained in a proper operating condition."
(Amended 1973, 1991)

For example, the practice of inserting a ticket in the printer and leaving it there while the vehicle is being driven to a delivery location is improper (and, as you will see shortly, is specifically prohibited). Obviously, it will be difficult or impossible for the inspector to determine whether the equipment is being used properly in the course of a field examination. You may, however, question the operator about how the device is used and advise him or her of requirements; this should certainly be done when complaints have been received. It is often possible to detect inadequate maintenance from the physical condition of the equipment at the time of the inspection. Look for evidence such as excessive dirt and grease, leaks, dents, or premature wear or need for adjustment. Broken or cracked glass over the register should be cited, since it may affect the readability of indications.

The provision regarding equipment at a single location that errs predominately in favor of the owner or operator is intended to discourage the abuse of tolerances. Weighing and measuring devices are required to be adjusted as close as possible to a zero error condition, not to tolerances, which are the legal limits of inaccuracy. If the operator of a number of tank meters makes it a practice to adjust all of them as close as possible to the tolerance rather than to zero error, the cumulative effect can be a significant advantage for him or her, and a significant disadvantage to the customers, even though the tolerances only permit a small degree of error for an individual device. The system of tolerances can only be effective if it can be assumed that for a large number of devices that perform within the tolerances, some err slightly in favor of the owner, some in favor of the consumer, so that the average effect is truly insignificant.

In accordance with this requirement, an inspector can reject all metering devices at a single location even though none of them individually is out of compliance. But such an action could obviously cause considerable disruption of business, not only for the operator, but for customers who depend upon scheduled deliveries. Handbook 44 does not provide guidelines for the interpretation of this requirement; however, many jurisdictions have specific policies in regard to this requirement. Even if your jurisdiction has such a policy, you will probably be required to exercise judgment in making a determination. To provide you with more flexibility in applying G-UR.4.1. the phrase "near the tolerance limit" was removed from the General Code in 1991.

MARKING

The most authoritative source of technical information about a vehicle-tank meter -- or any other weighing or measuring device -- is the manufacturer. Because such information is often needed by the operator, by repairpersons, and by weights and measures inspectors, the name of the manufacturer must be readily available. But the company name is often not sufficient to identify the device for the purpose of obtaining specific information about it. Most manufacturers of vehicle tank meters make more than one model of meter, and some make many. Furthermore, design changes and new features are sometimes incorporated into existing models. So the only way of positively identifying a particular meter is by using a system of individual serial numbers. These three basic items of information -- the manufacturer's name, the model designation, and the serial number -- are required to be displayed clearly and permanently on the device where they will be visible without having to use a tool to dismantle the equipment. The model and serial numbers shall each be designated with a term which clearly identifies it as such. (Note that the serial number is only required for devices manufactured since the beginning of 1968.) Devices that are covered by a National Type Evaluation Program (NTEP) Certificate of Conformance (CC) must also be clearly and permanently marked with the NTEP CC number as outlined below. In addition to the required markings outlined above, nonretroactive as of January 1, 2002, remanufactured devices and remanufactured main elements must be clearly and permanently marked with the name of the last remanufacturer or distributor and the model designation assigned by the remanufacturer or distributor, if different from the original model designation.

G-S.1. Identification. - All equipment, except weights and separate parts necessary to the measurement process but not having any metrological effect, shall be clearly and permanently marked for the purposes of identification with the following information:

(a) the name, initials, or trademark of the manufacturer or distributor;

(b) a model designation that positively identifies the pattern or design of the device;

(c) the model designation shall be prefaced by the term "Model," "Type," or "Pattern." These terms may be followed by the term "Number" or an abbreviation of that word. The abbreviation for the word "Number" shall, as a minimum, begin with the letter "N" (e.g., No or No.) The abbreviation for the word "Model" shall br "Mod" or "Mod."
[Nonretroactive January 1, 2003]
(Added 2000) (Amended 2001)

[Note: Prefix lettering may be initial capitals, all capitals or all lower case.]

(d) except for equipment with no moving or electronic component parts, a nonrepetitive serial number;
[Nonretroactive as of January 1, 1968]

(e) the serial number shall be prefaced by words, an abbreviation, or a symbol, that clearly identifies the number as the required serial number; and
[Nonretroactive as of January 1, 1986]

(f) the serial number shall be prefaced by the words "Serial Number" or an abbreviation of that term. Abbreviations for the word "Serial" shall, as a minimum, begin with the letter "S," and abbreviations for the word "Number" shall, as a minimum, begin with the letter "N" (e.g., S/N, SN, Ser. No, and S No.).
[Nonretroactive as of January 1, 2001]

(g) For devices that have an NTEP Certificate of Conformance (CC) Number or a corresponding CC addendum number, the NTEP Certificate of Conformance Number, which shall be prefaced by the terms "NTEP CC," "CC," or "Approval." These terms may be followed by the term "Number" or an abbreviation of that word. The abbreviation for the word "Number" shall, as a minimum, begin with the letter "N" (e.g., No or No.)
[Nonretroactive as of January 1, 2003]

The required information shall be so located that it is readily observable without the necessity of the disassembly of a part requiring the use of any means separate from the device.
(Amended 1985, 1991, 1999, 2000, and 2001)

G-S.1.1. Remanufactured Devices and Remanufactured Main Elements. - All remanufactured devices and remanufactured main elements shall be clearly and permanently marked for the purposes of identification with the following information:

(a) the name, initials, or trademark of the last remanufacturer or distributor;

(b) the remanufacturer's or distributor's model designation if different than the original model designation.

[Nonretroactive as of January 1, 2002.]
(Added 2001)

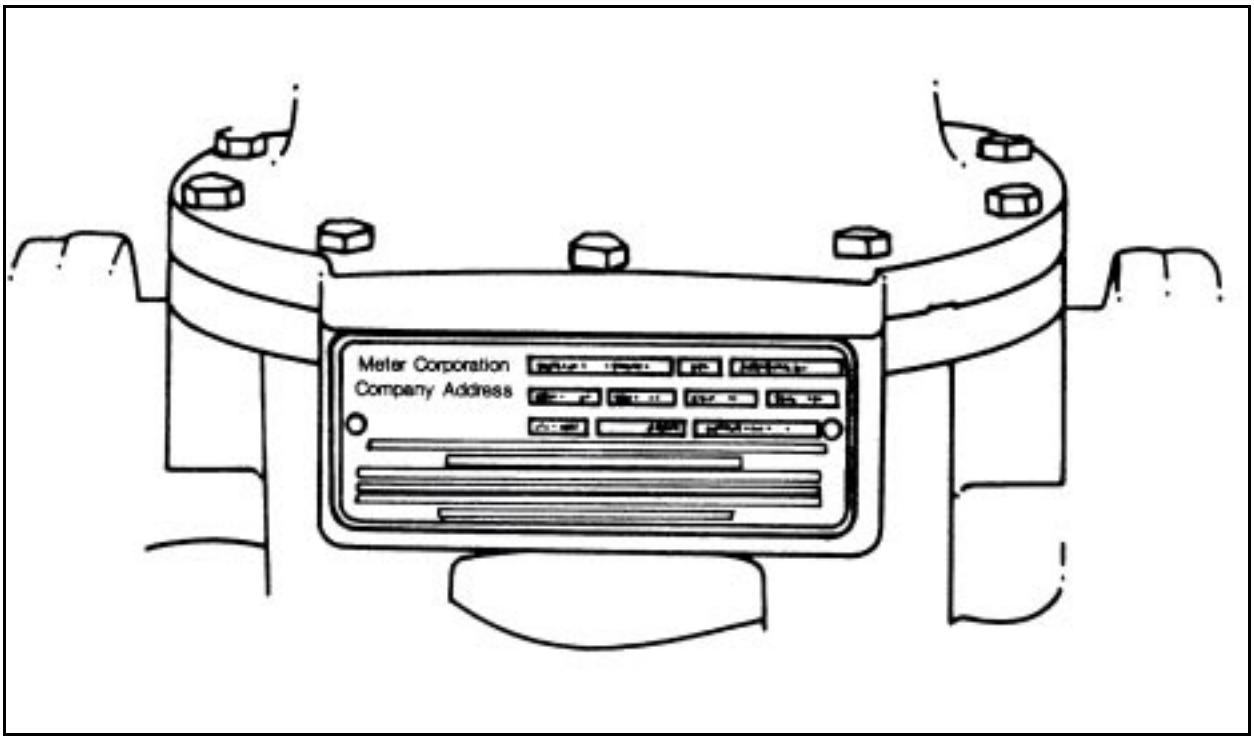


Figure 5-3. Identification Plate

Most manufacturers imprint or etch this information on a thin metal plate, which is affixed to one of the surfaces of the meter body, as in the example shown in Figure 5-3. If the register and/or ticket printer are made by a company other than the manufacturer of the meter, a separate identification plate is usually affixed to each.

This identifying information must be permanently marked. This means that it must not be removable or alterable, unless provision is made that removal or alteration will be readily evident. So an identification plate should be attached in some way that prevents its removal without mutilating or destroying it. Rivets should be used to attach the plate, not removable screws; this will prevent the plate from being replaced or transferred to another device. To prevent alteration of the imprinted information, some manufacturers use a plate made of pressure-sensitive material that will show clearly any attempt to erase original markings or alter them in any way. The use of pressure-sensitive identification plates may, however, cause problems

if the plate is located in a place where it is exposed to frequent abrasion, since markings may be accidentally obliterated.

Two specific marking requirements apply to vehicle-tank meters: these relate to limitations of use and discharge rates. We have referred to them in our discussion of General Considerations regarding selection, installation, and use and maintenance.

S.5.1. Limitation of Use. - If a meter is intended to measure accurately only liquids having particular properties, or to measure accurately only under specific installation or operating conditions, or to measure accurately only when used in conjunction with specific accessory equipment, these limitations shall be clearly and permanently stated on the meter.

S.5.2. Discharge Rates. - A meter shall be marked to show its designed maximum and minimum discharge rates. However, the minimum discharge rate shall not exceed 20 percent of the maximum discharge rate.

This information may be displayed on the same plate as the meter identification, or in another place. The reason for the limitation on the maximum discharge rate will be discussed in detail in the next chapter.

INDICATING AND RECORDING ELEMENTS

The remainder of the Inspection involves the operating components of the system: the indicating and recording elements, the measuring elements, and the piping. We turn first to the indicating and recording elements.

Design

According to Handbook 44, an indicating element is "an element incorporated in a weighing or measuring device by means of which its performance relative to quantity or money value is "read" from the device itself. . . ." A recording element permanently records such a "reading." An indicating or recording element that is used as the basis for determining the price of a commercial transaction is called a "primary" element. In general, only primary elements are covered by Handbook 44 specifications and requirements. All commercial measuring devices, including vehicle-tank meters, are required to have at least a primary indicating element.

S.1.1.1. General. - A meter shall be equipped with a primary indicating element and may also be equipped with a primary recording element.

[Note: Except for systems used solely for the sale of aviation fuel into aircraft and for aircraft-related operations, vehicle-tank meters shall be equipped with a primary recording element as required by paragraph UR.2.2.1.] (Amended 1993)

A system may also have one or more indicating elements that are not primary elements, because they are not used as the basis for the transaction. For example, many vehicle-tank meters are equipped with totalizers, which indicate cumulative quantities, and are used by the operator to monitor sales and as a means of detecting pilfering.

Except for systems used to deliver aviation fuel into aircraft and for aircraft-related operations, a vehicle-tank meter must be equipped with a ticket printer. The ticket printer must be used for all sales, and a copy of the ticket shall be left with the customer unless otherwise specified by the customer.

UR.2.2. Ticket Printer; Customer Ticket. - Vehicle-mounted metering systems shall be equipped with a ticket printer which shall be used for all sales where product is delivered through the meter. A copy of the ticket issued by the device shall be left with the customer at the time of delivery or as otherwise specified by the customer.
(Added 1993) (Amended 1994)

UR.2.2.1. Exceptions for the Sale of Aviation Fuel. - The provisions of UR.2.2. Ticket Printer; Customer Ticket shall not apply to vehicle-mounted metering systems used solely for the sale of aviation fuel into aircraft and for aircraft-related operations.
(Added 1999)

The unit of measure customarily used in sales of liquid products in the U.S. inch-pound system is the gallon. In order to prevent the confusion that would certainly arise from the use of different units by different vendors, vehicle-tank meters must be designed to indicate and record, if a recording element is employed, deliveries in terms of gallons. It should be kept in mind; however, that use of the weights and measures of the Metric System is lawful throughout the United States and deliveries may be indicated and recorded in terms of liters.

S.1.1.2. Units. -

(a) A meter shall indicate, and record if the meter is equipped to record, its deliveries in terms of liters (gallons). Fractional parts of the liter (gallon) shall be in terms of either decimal or binary subdivisions.

(b) When it is an industry practice to purchase and sell milk by weight based upon 1.03 kg/L (8.6 lb/gal), the primary indicating element may indicate in kilograms (pounds) and decimal kilograms (pounds). The weight value division shall be a decimal multiple or submultiple of 1, 2, or 5. (See S.5.5.)

Fractional parts of gallons may also be indicated or recorded, whether in terms of decimal or binary subdivisions (half-gallons, quarts, pints, etc.). As was discussed under the heading of General Considerations regarding selection of a design appropriate to its application, milk-metering systems and meters used for retail deliveries of liquid fuel must indicate deliveries using subdivisions equivalent to a 0.1 gallon or less.

Primary elements must also be designed to be reset to a definite zero indication before the commencement of a delivery. This assures that a reading of the amount actually delivered will be provided at the end of the delivery, when the transaction is completed. This provision protects both buyer and seller. If resetting to zero was not required, the buyer could not be assured of the amount received unless he or she was present to record the initial cumulative reading; because the initial reading would not be available at the conclusion of the delivery, there would be no way of verifying the amount if it was disputed. (Primary recording elements are not required to be resettable, since cumulative readings can be permanently recorded at the beginning and end of the delivery.)

S.1.1.5. Return to Zero. - Primary indicating elements shall be readily returnable to a definite zero indication. Means shall be provided to prevent the return of primary indicating elements, and of primary recording elements if these are returnable to zero, beyond their correct zero position.

Specific requirements apply to the design of indicating and recording elements to prevent any reading other than the actual amount of the delivery being displayed, either accidentally or as the result of deliberate manipulation by the operator.

S.1.1.4. Advancement of Indicating and Recording Elements. -Primary indicating and recording elements shall be susceptible to advancement only by the mechanical operation of the meter. However, a meter may be cleared by advancing its elements to zero, but only if:

(a) the advancing movement, once started, cannot be stopped until zero is reached, or

(b) in the case of indicating elements only, such elements are automatically obscured until the elements reach the correct zero position.

Most mechanical registers incorporate revolving indicating wheels. The wheels must be designed so that they can only be advanced by the mechanical operation of the meter; in other words, they can only be advanced when product is moving through the meter -- an operator can not simply advance the wheels so that they indicate an amount greater than that actually delivered. There is one exception to this requirement: resetting of the register by advancement -- without the operation of the meter -- is permitted, provided that the motion of the wheels, once begun, can not be halted until zero is reached or that the indications are hidden from view until the reset is completed. To meet this requirement, many mechanical registers are designed with shutters that cover the wheels during the reset and are raised when it has been completed.

Electronic registers generally blank out the display during the reset. Most of them incorporate a segment check feature that displays the figure 8 momentarily for all digits in the display before zeros appear. (The figure 8 contains all the segments that are used to display the other numbers: if all the segments of the 8 appear, all other numbers can be displayed correctly.)

Your inspection of the design of indicating and recording elements should consist of the following steps:

- Identify all primary indicating and recording elements.
- Determine whether the units displayed are correct (that they do not exceed the equivalent of 0.5 L (0.1 gal) or 0.5 kg (1 lb) for milk or 0.5 L (0.1 gal) for home heating fuel or 5 L (1 gal) for other products).
- Activate the reset and observe the element to verify that no indications are readable until the register shows a definite zero status.

Readability

To minimize the risk of errors and the possibility of misrepresentation, the customer, as well as the operator, must be able to read and understand the information provided by primary indicating and recording elements. For this reason, a number of general and specific requirements are established in Handbook 44 regarding the design, size, uniformity, and durability of primary elements that employ either analog or digital representations. Paragraph G-S.5.1 of the General Code includes the basic requirements.

G-S.5. Indicating and Recording Elements

G-S.5.1. General. - All weighing and measuring devices shall be provided with indicating or recording elements appropriate in design and adequate in amount. Primary indications and recorded representations shall be clear, definite, accurate, and easily read under any conditions of normal operation of the device.

This paragraph also provides the primary basis for evaluating the readability of primary elements during your inspection: indications and recorded representations must be "clear, definite, accurate, and easily read under any conditions of normal operation of the device." This reflects the purpose and intent of the various specific requirements that relate to these elements -- to assure that both buyer and seller can read and understand the information displayed by the device both during and at the conclusion of the transaction.

Even if the device conforms with all the specific requirements that are described below, you must satisfy yourself that indications and representations meet the general test of readability established in G-S.5.1. The only means of determining this is to observe the elements critically, not at close range, as you might when checking a specific item, but from the position from which they would normally be viewed during a delivery. From this perspective you should ask yourself: Can a customer, who may not be familiar with the equipment or its indications, both read and understand them? If the answer is negative, you must determine the specific cause of inadequate readability so that the owner or operator can be informed of what specific repairs or changes are necessary in order to bring the device into conformance with this requirement.

Several general requirements relating to readability involve the design of the elements themselves. As you will recall from our discussion in Chapter 3, two basic types of indication and representation are distinguished: analog and digital. Design requirements for these two types are necessarily somewhat different.

G-S.5.2. Graduations, Indications, and Recorded Representations.

G-S.5.2.1. Analog Indication and Representation. -Graduations and a suitable indicator shall be provided in connection with indications designed to advance continuously.

G-S.5.2.2. Digital Indication and Representation. - Digital elements shall be so designed that:

(a) All digital values of like value in a system agree with one another.

(b) A digital value coincides with its associated analog value to the nearest minimum graduation.

(c) A digital value "rounds off" to the nearest minimum unit that can be indicated or recorded.

(d) *A digital zero indication includes the display of a zero for all places that are displayed to the right of the decimal point and at least one place to the left. When no decimal values are displayed, a zero shall be displayed for each place of the indicated division. [Nonretroactive as of January 1, 1986.]*

(Amended 1973 and 1985)

Subparagraph G-S.5.2.1 simply states that an analog device must be equipped with appropriate features for this type of indication: graduations and a suitable indicator. Specific requirements relating to graduations and indicators for analog devices are included in the Vehicle-Tank Meters Code and are described below.

The first two items in the subparagraph on digital devices refer to systems which incorporate more than one primary element. If a tank truck system is equipped with both a register and a ticket printer, the values indicated and recorded must agree as specified. If both elements are digital, values displayed must agree exactly (as you will learn below, recorded representations are required to be digital). If the register is analog, values must agree to the nearest minimum graduation. For example, if the smallest graduated intervals on the register represent 0.1 gallon and the register indicates 100.05 gallons (with the pointer halfway between the 0.0 and the 0.1 graduations on the right-hand indicating wheel), a ticket produced by the printer could display a value of 100.1 gallons, since that would be the quantity indicated by the analog indicator with its pointer on the nearest graduation. The allowance is necessary because of the fundamental difference between analog and digital devices: the former indicate change continuously while the latter indicate change in increments.

For vehicle-tank meters, the requirement that a digital device "round off" to the nearest unit means that the displayed value will change when the actual delivery is about halfway between two successive indicated amounts. So, for example, if a digital register has an increment of 0.1 gallon and currently reads 100.0 gallons, this represents the actual delivery of some quantity between 99.950 and 100.049 gallons; when 100.050 gallons have been delivered, the indication will change to 100.1.

The requirement that a digital zero indication include zeros for each digit to the right of the decimal point that can be displayed and a zero for at least one place to the left of the decimal point assures that the smallest quantity that the device is capable of measuring and indicating will be apparent before delivery begins. The customer will thus be aware of the sensitivity of the device and of the minimum units that will be employed in completing the transaction.

Conformance with the general requirements for digital devices set forth in subparagraph G-S.5.2.2 can only be determined with the system in operation, and is thus most efficiently checked during the Test portion of the examination. We will refer to these procedures at the appropriate point in the Test, which is described in Chapter 6.

Three additional general requirements relate to the size and character, values, and permanence of both analog and digital indications and recorded representations.

G-S.5.2.3. Size and Character. - In any series of graduations, indications, or recorded representations, corresponding graduations and units shall be uniform in size and character. Graduations, indications, or recorded representations that are subordinate to or of a lesser value than others with which they are associated shall be appropriately portrayed or designated. (Made retroactive as of January 1, 1975.)

G-S.5.2.4. Values. - If graduations, indications, or recorded representations are intended to have specific values, these shall be adequately defined by a sufficient number of figures, words, symbols, or combinations thereof, uniformly placed with reference to the graduations, indications, or recorded representations and as close thereto as practicable, but not so positioned as to interfere with the accuracy of reading.

G-S.5.2.5. Permanence. - Graduations, indications, or recorded representations and their defining figures, words, and symbols shall be of such character that they will not tend easily to become obliterated or illegible.

On a mechanical register of the revolving wheel type, like the one depicted in Figure 5-4, each wheel represents a single digit of a decimal number. The specific values (tenths, ones, hundreds, etc.) represented by each wheel are distinguished by the relative position of the wheel (tenths to the immediate right of the decimal point, ones to the immediate left, etc.); so on this type of indicator the size and character of the numerals and graduations are generally the same (although the digits to the right of the decimal point sometimes have smaller numbers or a contrasting color background to facilitate reading). Decimal subdivisions of the values represented by any of the wheels are indicated on the next wheel to the right, except of course, for the rightmost wheel. This wheel may have subdivisions marked, as in the example shown; values are read by using the index to the right. If, as is usually the case, there is only one level of subdivision, the values of the divisions are usually obvious without literal designations.

As you inspect this type of register, observe the rightmost indicating wheel critically. The values represented by any divisions on this wheel should be clear to a customer who is not familiar with the register or its indications, and there should be no confusion between major divisions and subdivisions.

Indicators of whatever type should be protected from abrasion and accumulations of dirt and grease by a glass covering. Even with this protection, however, readings can be obscured by cracks, scratches, or dirt on the cover glass, and these conditions, though usually minor, must be remedied. If well protected, the indicators will usually meet the requirement for permanence. But you should always check the readability of the indicators anyway. In some wheel-type registers the clearance between the wheels and the reset shutter is very small, and when the mechanism wears, the closure of the shutter and/or the movement of the wheels may produce scratches or chips on the numbers and graduations that are painted on the wheels. When this process reaches the point where readability is affected, the wheels must be repainted or replaced and the shutter mechanism must be adjusted.

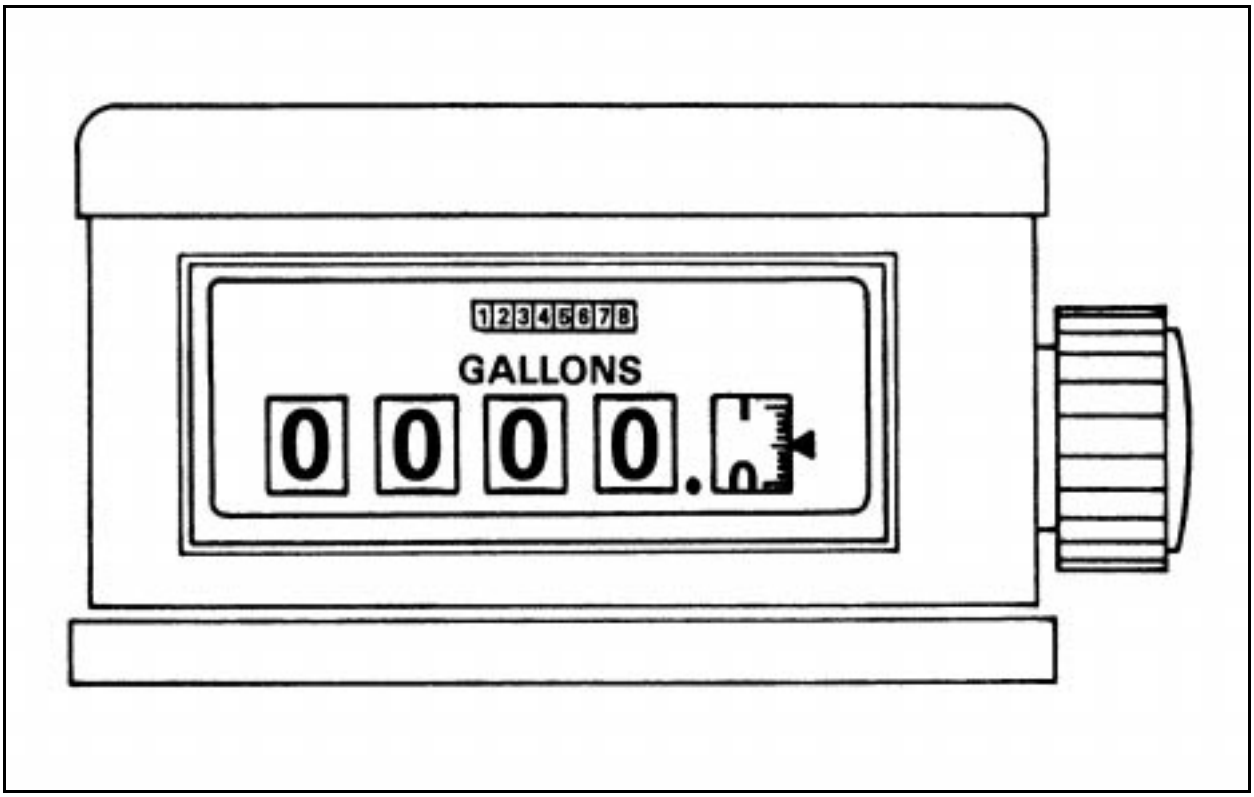


Figure 5-4. Size and Character of Indicating Elements, Mechanical Register

A vehicle-tank's metering system that is equipped with a ticket printer makes a permanent record of each commercial transaction. The numbers, symbols, lettering, and other markings on these records, referred to as recorded representations, must also be readable and understandable. One paragraph in the General Code deals specifically with recorded representations.

G-S.5.6. Recorded Representations. - Insofar as they are appropriate, the requirements for indicating and recording elements shall be applicable also to recorded representations. All recorded values shall be printed digitally.
[Made retroactive 1990] (Amended 1975)

A ticket or invoice produced by a printer includes a representation of the same information that is displayed on the register. The application of the same basic requirements to both types of indication is therefore logical. For example, since the register is required to display the units of measurement -- gallons -- a printed ticket should also provide this information. If the device is capable of computing the sale price, the printed information should also include the same unit price that is displayed on the outside of the device

(see below). In addition, the printed representation itself must meet the general requirement for readability described above.

There is, however, one way in which the printed representation and the register indication may differ: according to paragraph G-S.5.6, the recorded representation must be digital, regardless of whether the register indication is analog or digital. That is, the quantity delivered (as well as the total price and unit price if the system is of the computing type) must appear on the ticket as numbers. It would not be acceptable, for example, for the printer to show a representation of indicating wheels or a dial with graduations and an indicator, even if this is the means by which register indicates amounts and values.

A subparagraph of G-S.5.6 includes a table that sets forth correct standard abbreviations for metric units that are used on recorded representations produced by weighing and measuring devices. One abbreviation that is relevant to vehicle-tank metering systems is that for the liter, which may be represented by either L (uppercase) or 1 (lowercase).

In addition to the indications of quantity, price, units, and so on, many weighing and measuring devices have a variety of manual operating controls, switches, lights, and other features. The operator of the device may be aware from long experience of the function and correct operation of such features, but the customer must also know whether and how such features affect the indicated measurement and must also be able to monitor the operator's actions during the transaction, especially the manipulation of non-automatic control elements. For this reason, the General Code requires identifying markings and lettering for all such features, and further requires that these markings be readable.

> ***G-S.6. Marking, Operational Controls, Indications, and Features.*** *- All operational controls, indications, and features, including switches, lights, displays, pushbuttons, and other means, shall be clearly and definitely identified. The use of approved pictograms or symbols shall be acceptable. [Nonretroactive as of January 1, 1977.] (Amended 1978, 1995)*
>
> **G-S.7. Lettering.** - All required markings and instructions shall be distinct and easily readable and shall be of such character that they will not tend to become obliterated or illegible.

The number of separate features that require marking on a vehicle-tank metering system will depend largely upon the design of the system. A system equipped with only a mechanical register, like the one shown earlier in Figure 5-4, and with no such auxiliary devices as a ticket printer, preset, or automatic temperature compensator, will generally require markings only for the indicating elements themselves (graduations, number values, units, etc.) and for the reset control. On a more full-featured system, however, like the electronic register and printer shown in Figure 5-5, considerably more identifying marking and instructions will be required. Instructions actually printed on the device may be very rudimentary, like those for the ticket printer in the example below, but they should be sufficient to indicate both function and basic operation.

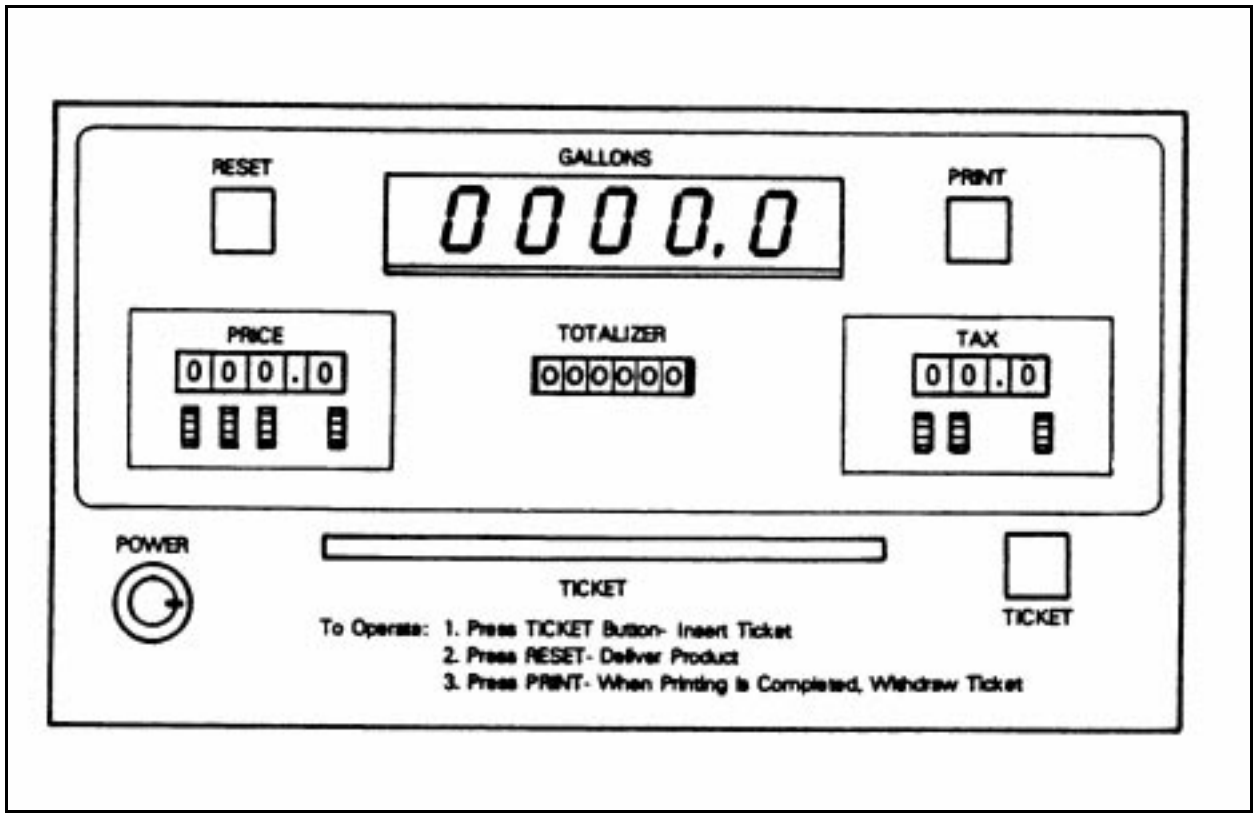


Figure 5-5. Marking of Controls and Other Features

More specific requirements regarding readability are included in the Vehicle-Tank Meters Code. Because electronic registers are digital devices, and thus do not have either graduations, indicators, or permanent values, these requirements relate primarily to mechanical type indicators.

S.1.2. Graduations.

S.1.2.1. Length. - Graduations shall be so varied in length that they may be conveniently read.

S.1.2.2. Width. - In any series of graduations, the width of a graduation shall in no case be greater than the width of the minimum clear interval between graduations, and the width of main graduations shall be not more than 50 percent greater than the width of subordinate graduations. Graduations shall in no case be less than 0.2 mm (0.008 in) wide.

S.1.2.3. Clear Interval Between Graduations. - The clear interval shall be not less than 2.5 mm (0.10 in). If the graduations are not parallel, the measurement shall be made:

(a) along the line of relative movement between the graduations at the end of the indicator, or

(b) if the indicator is continuous, at the point of widest separation of the graduations.

(Amended 1986)

S.1.3. Indicators

S.1.3.1 Symmetry. - The index of an indicator shall be symmetrical with respect to the graduations at least throughout that portion of its length associated with the graduation.

S.1.3.2. Length. - The index of an indicator shall reach to the finest graduations with which it is used, unless the indicator and the graduations are in the same plane, in which case the distance between the end of the indicator and the ends of the graduations, measured along the line of the graduations, shall be not more than 1.0 mm (0.04 in).

S.1.3.3. Width. - The width of the index of an indicator in relation to the series of graduations with which it is used shall be not greater than

(a) the width of the narrowest graduation*, and
[*Nonretroactive as of January 1, 2002]
(Amended 2001)

(b) the width of the minimum clear interval between graduations.

When the index of an indicator extends along the entire length of a graduation, that portion of the index of the indicator that may be brought into coincidence with the graduation shall be of the same width throughout the length of the index that coincides with the graduation.

S.1.3.4. Clearance. - The clearance between the index of an indicator and the graduations shall in no case be more than 1.5 mm (0.06 inch).

S.1.3.5. Parallax. - Parallax effects shall be reduced to the practicable minimum.

S.1.3.6. Travel of Indicator. - If the most sensitive element of the primary indicating element utilizes an indicator and graduations, the relative movement of these parts corresponding to the smallest indicated value shall not be less than 5 mm (0.20 in).

Figure 5-6 illustrates the specifications for the length and width of graduations and the clear interval between them (measured from the facing edges of successive graduations). Obviously,

if graduations are too thin, they may not be readable during the normal use of the equipment. But graduations must also not be too wide in proportion to the clear intervals between them. There are two reasons for this. The first is to avoid any confusion about which is the graduation and which is the interval: the graduation is conventionally thinner than the interval.

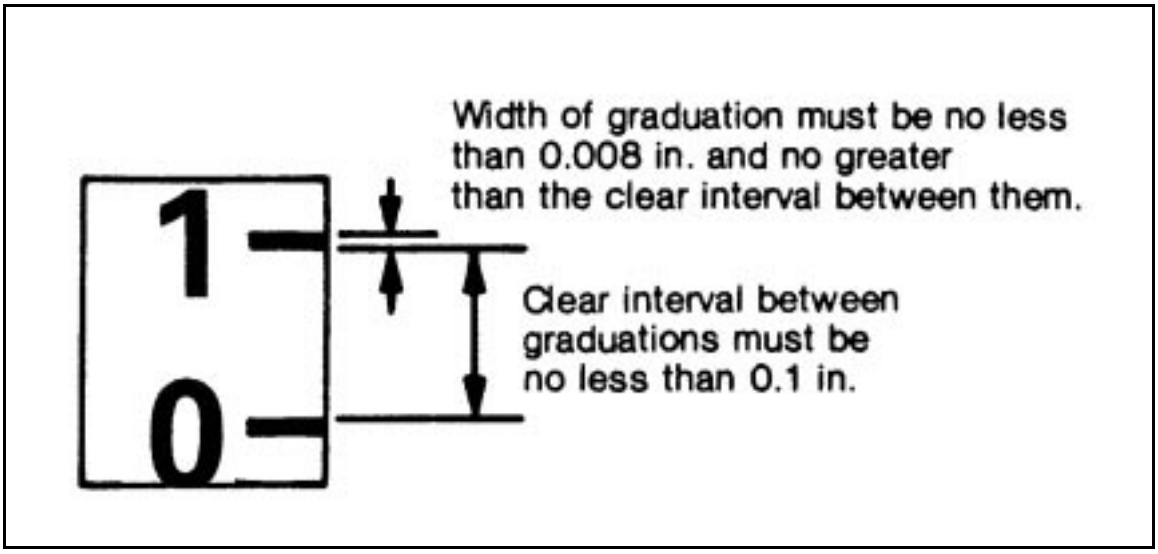


Figure 5-6. Length and Width of Graduations

The second reason has to do with the nature of a graduation. A graduation represents a division between two values, but the division itself ideally has no width and no value. Of course, for practical purposes, graduations must have some width, or they could not be read. Therefore, a minimum width (0.008 in) is specified. On the other hand, the wider the graduation in proportion to the interval between graduations, the larger the value it incorporates, and this can affect readability significantly. To see how, let us consider an example.

In accordance with the specifications of S.1.2, a graduation may be no wider than the clear interval between graduations. In the example shown in Figure 5-7, the graduations and intervals are of equal width, each one thus comprising 1/20th of the circumference of the wheel. If this is a 1/10th-gallon wheel, each complete revolution indicates 1 gallon delivered. So each interval and each graduation thus represents 0.05 gal.

If the operator follows the convenient practice of reading the exact division whenever any part of the pointer coincides with any part of the graduation, the reading could be off by as much as 0.025 gal (5.775 cu in). In our example, the operator would read 50.00 gal, whereas the actual reading is much closer to 49.98 gal. From the point of view of a delivery of 1,000 gallons of product, this amount (about 1/50th of a gallon) is obviously insignificant. However, if a weights and measures inspector is testing this meter, such a small amount can be very significant, since it is only slightly less than one-quarter of the acceptance tolerance for a 50-gallon test draft. If the inspector were to read the indication in Figure 5-7 as 50.00 gal and the prover showed a minus error within

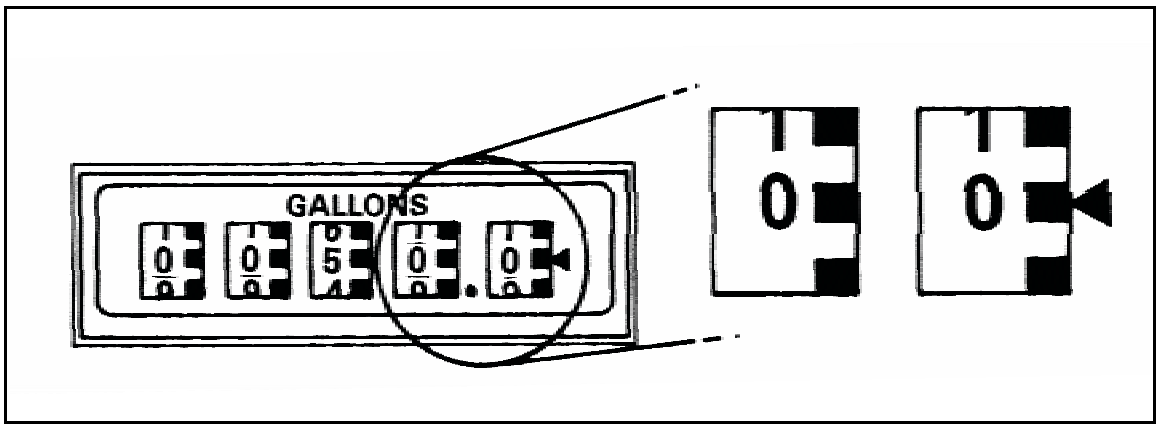


Figure 5-7. Width of Graduations

4.62 cu in of the applicable tolerance, the meter could be erroneously rejected. The inspector would obviously try to visually subdivide the graduation to gain a more accurate reading, but this could be difficult, especially if the edges of the graduation are indistinct.

It is very unlikely that you would ever encounter such a situation in the field, since the clear intervals on most indicating wheels are proportionately much wider than the graduations (commonly in a ratio of 20:1 or more). But you should understand and be able to explain the reason for the requirement if necessary. And you should always make a visual inspection to assure yourself that you are not dealing with an atypical situation. If it appears that the graduations are larger than the intervals between them, or if the smallest clear interval appears to be thinner than the point of a pencil or ballpoint pen, it may be necessary to actually measure the dimensions. Special equipment will probably be needed for this.

The index of the indicator is a pointer, which is painted (or sometimes cut out) from the sheet metal face plate that surrounds the wheels (see Figure 5-8). This design virtually eliminates parallax effects (apparent differences in the relative position of two observed objects -- in this case the wheel and the pointer -- depending on the position of the observer) since both are thus in the same plane. The center of the pointer edge that faces the graduation must be used for an accurate reading, and the center can only be readily located if the end of the pointer is symmetrical. Limiting the space between the end of the pointer and the wheel and limiting the width of the pointer also facilitate readability.

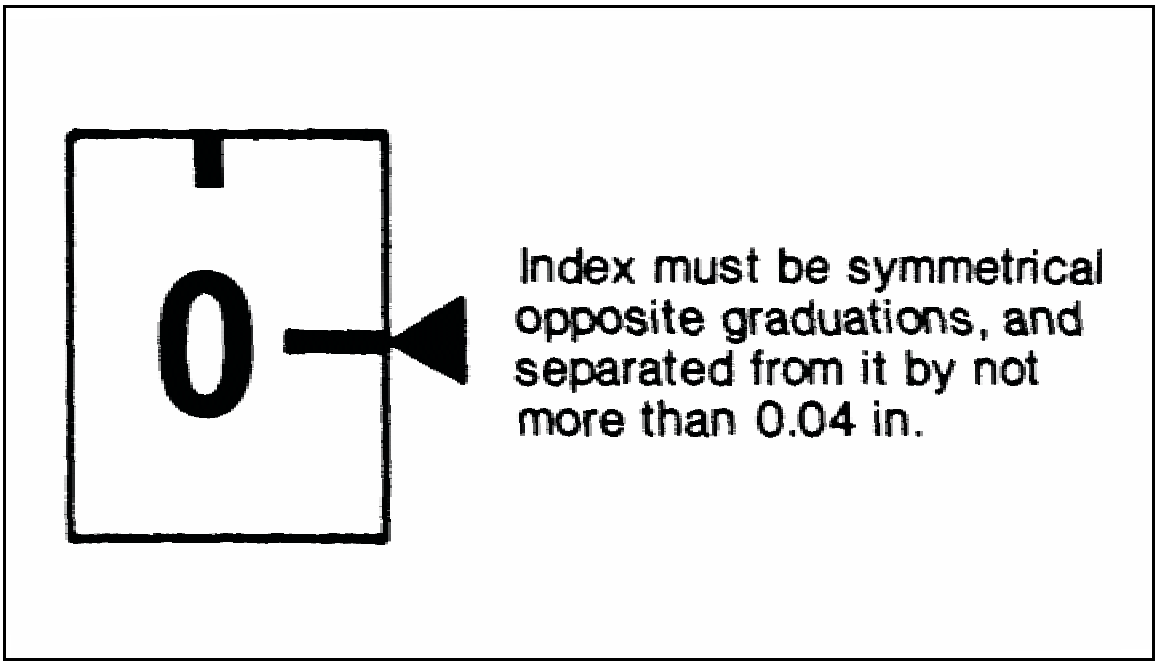


Figure 5-8. Index of the Indicator, Mechanical Register

Values of Intervals

The distance between the center of one graduation and the center of the next graduation is referred to as the graduated interval (see Figure 5-9). This interval has an associated value. In the example shown this value is 0.1 gal: the passage of the pointer through the graduated interval represents 0.1 gal of product delivered.

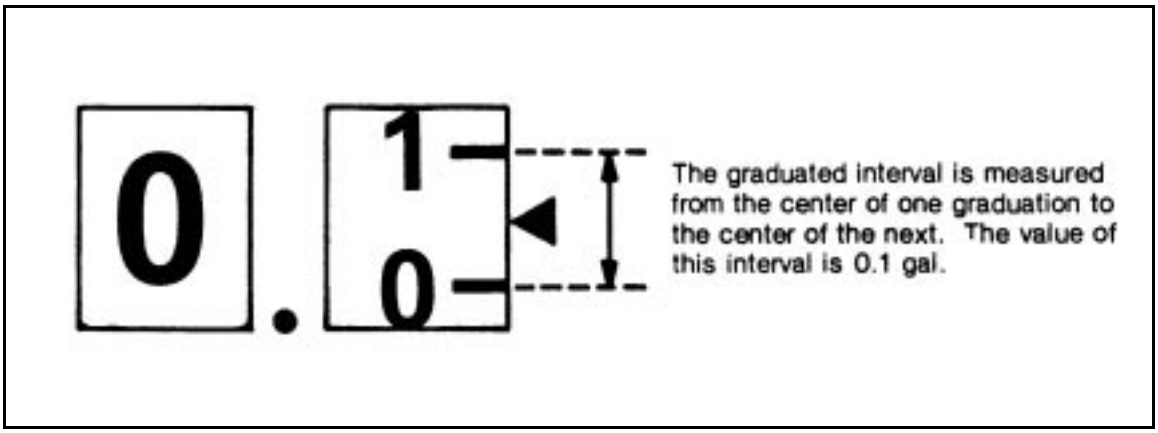


Figure 5-9. Values of Intervals

The equivalent of the graduated interval for a digital indicator is the increment. The increment is the smallest change in value that can be indicated or recorded. Two paragraphs in the General Code include requirements for graduated intervals or increments.

G-S.5.3. Values of Graduated Intervals or Increments. - In any series of graduations, indications, or recorded representations, the values of the graduated intervals or increments shall be uniform throughout the series.

G-S.5.3.1. On Devices That Indicate or Record in More than One Unit. -On devices designed to indicate or record in more than one unit of measurement, the values indicated and recorded shall be identified with an appropriate word, symbol, or abbreviation. (Amended 1978, 1986) (Made retroactive 1990)

The requirement regarding uniformity simply means that in any given series the value of the interval or increment must not change at any time. Any non-linear progression would obviously be confusing -- and could be deceptive -- especially on a wheel type indicator, since the next value may not be visible at the same time as the current value. The operator or customer must be able to determine what the next indication will be even if it can not be seen, in order to regulate the delivery. On most digital indicators, only the current value is visible at any moment.

The requirement regarding dual indications (U.S. inch-pound and metric) is intended to assure that devices so equipped are clearly and adequately marked to prevent confusion, while at the same time not discouraging conversion to the metric system.

Computing-type Devices

A computing-type device is one that indicates the total money value of the delivery, in addition to the amount. Most mechanical registers do not have this capability, primarily because of the complicated and costly design that would be required to permit variation of the unit price and to provide for the different taxing formulas -- some based on quantity, others on price -- that are in force in different jurisdictions. (Many tank trucks operate in more than one taxing jurisdiction.) Most electronic registers, on the other hand, do have full computing capability, with unit price variation and tax formulas programmable. The advantages afforded to operators will in all likelihood lead to increased use of such devices. Several specific requirements are established to assure that computing-type devices provide information that is accurate and can be readily understood by both the seller and the buyer.

One such essential item of information is the unit price of the product, which must be displayed in the same units that are indicated on the register (for example, price per gallon). This requirement also applies to a printed ticket, if the system produces one. The ticket must also display the total number of gallons delivered, including any fractional quantity (in accordance with the requirements for agreement between displayed values described above).

S.1.4. Computing-type Device.

S.1.4.1. Display of Unit Price. - In a device of the computing type, means shall be provided for displaying on the outside of the device, in a manner clear to the operator and an observer, the unit price at which the device is set to compute. (Amended 1983)

S.1.4.2. Printed Ticket. - If a computing-type device issues a printed ticket which displays the total computed price, the ticket shall also have printed clearly thereon the total quantity of the delivery, the appropriate fraction of the quantity, and the price per unit of quantity.
(Amended 1989)

UR.1.2. Unit Price. - There shall be displayed on the face of a device of the computing type the unit price at which the device is set to compute.

Computing-type systems employed with vehicle-tank meters can compute and display or record sales prices for unit prices of up to $0.999 per gallon, and some have capability for unit prices up to $9.999 per gallon. The range of total prices that can be computed will depend upon the design of the system and the unit price for which it is set to compute at any given time, but a computing-type device must in general be capable of computing a price for any delivery that is made. It must not, for example, be necessary to multiply the computed value by some factor to determine the actual price of the sale. This requirement is set forth in the Vehicle-Tank Meters Code.

S.1.4.3. Money-Value Computations. - Money-value computations shall be of the full-computing type in which the money value at a single unit price, or at each of a series of unit prices, shall be computed for every delivery within either the range of measurement of the device or the range of the computing elements, whichever is less. Value graduations shall be supplied and shall be accurately positioned. The value of each graduated interval shall be 1 cent. On electronic devices with digital indications, the total price may be computed on the basis of the quantity indicated when the value of the smallest division indicated is equal to or less than 0.2 L (0.1 gal) or 0.2 kg (1 lb).
(Amended 1979, 1989)

This paragraph also sets forth specific requirements for both analog and digital computing-type devices. Almost all such devices now in use are electronic and digital, and it is not likely that analog computing-type indicating and recording elements will ever be in common use on vehicle-tank metering systems. However, two requirements are established for analog computing-type devices: they must be equipped with graduations, and the value of each graduated interval must be one cent. The purpose of both of these requirements is to assure that indicated money values can be read accurately to the nearest cent. A smaller money value division is unnecessary and might even be confusing, since the cent is the smallest

unit of U.S. currency. A larger division would also be confusing, and might even encourage improper or fraudulent use of the equipment, since accurate readings to within one cent could not be readily obtained and verified.

The requirement for digital devices has the same general purpose. Digital computing-type devices generally perform computations based upon the number of signals transmitted by the pulser. However, the pulser is designed to generate discrete pulses at quantity divisions. For example, many pulsers are designed to generate 10 discrete pulses per revolution in their normal operating mode, with each signal causing the quantity display to be incremented by 0.1 gallon. The result is that the money-value increment -- that is, the smallest change in money value that can be displayed -- is equal to the quantity increment multiplied by the unit price.

Consider the following example, showing a succession of indicated values when the unit price is $0.99 per gallon and the quantity increment is 0.1 gallon. As you can see, the smallest change in money value that can be displayed is $0.099 (which rounds to $0.10).

Quantity	Unit Price	Total Price	Change in Price
1.0 gal	$ 0.99/gal	$ 0.99	$ 0.099
1.1 gal	0.99/gal	1.09	0.099
1.2 gal	0.99/gal	1.19	0.099
1.3 gal	0.99/gal	1.29	0.099

This will cause no problem for commercial transactions in which the customer purchases a specific quantity of product. However, if the customer wishes to purchase a certain dollar value of product, it will only be possible to display the desired amount if it is a multiple of the money-value increment. Note, for example, that a system set as in the example above will not display a total sale of exactly $1.00 (or any other whole dollar amount). Delivery of many specific dollar amounts can thus only be done by estimation, halting delivery at some indefinite point between divisions, and can not be verified.

The requirement of S.1.4.3 relating to digital devices simply states that if money-value computations are derived in this way, the quantity increment must not exceed 0.1 gallon. This has the effect of limiting the range of inaccuracy under circumstances in which the customer wishes to purchase a specific dollar amount

of product or when the halting of delivery is indefinite (for example, when a tank is "topped off", or filled to its capacity) to the dollar value of 0.1 gallon of product at its current price.

In summary, you should inspect a computing-type device to determine that the unit price is correctly displayed. Conformance with requirements relating to the information printed on a ticket (if the device is equipped with a ticket printer) and to money-value computations is most efficiently checked when the system is operating. We will, therefore, refer to these procedures again in our discussion of the Test.

Advancement and Return to Zero

Specific requirements relating to the zero reset mechanism have been covered earlier in the section on the design of indicating and recording elements. However, one user requirement has not yet been discussed.

UR.2.1. Return of Indicating and Recording Elements to Zero. - The primary indicating elements (visual), and the primary recording elements when these are returnable to zero, shall be returned to zero immediately before each delivery is begun and after the pump has been activated and the product to be measured has been supplied to the measuring system.
(Amended 1981)

Most ticket printers are designed in such a way that a new ticket cannot be printed until the register has been reset to zero. This prevents a buyer from being charged for the preceding delivery in addition to his or her own, either by accident or by design. However, vehicle-tank meters are not required to be equipped with an interlock mechanism that prevents delivery from being resumed without resetting the register after this system has been deactivated (as gas pumps are required to be). Accordingly, an unscrupulous operator could insert a ticket in the printer before reaching the buyer's location, divert a quantity of product back to the tank (by simply running the delivery hose up to the fill opening of the truck) halt the delivery without resetting the meter, drive to the buyer's location and resume delivery. If the buyer is not present to observe the register reading before delivery begins and demand that it be reset, he or she could be fraudulently charged for a quantity of product that has not left the possession of the operator. Some electronic devices incorporate a "timeout" feature whereby a ticket is automatically printed after a specified time after delivery stops.

Additionally, Handbook 44 includes a user requirement which requires that a new ticket cannot be inserted into a device until immediately before a delivery and the ticket cannot be in the device while the vehicle is in motion on public roads.

UR.2.3. Ticket in Printing Device. - A ticket shall not be inserted into a device equipped with a ticket printer until immediately before a delivery is begun, and in no case shall a ticket be in the device when the vehicle is in motion while on a public street, highway, or thoroughfare.

These user requirements are intended to prohibit such fraudulent practice. It is, however, obviously impossible for an inspector to detect this particular type of misuse during a field examination. If complaints have been received, you should remind the operator that correct use is prescribed and warn him or her of the consequences of continued misuse. If there is reason to suspect that the operator is misusing metering equipment with the intent to defraud, consult your supervisor regarding further action. In some jurisdictions, an operator suspected of such practice may be placed under surveillance.

MEASURING ELEMENTS

After our discussion of the numerous and detailed specifications relating to the indicating and recording elements of a vehicle-tank metering system, it may seem surprising to you to learn that Handbook 44 includes no specific requirements for the meter itself, except that provision be made for sealing it. Of course the system is required to perform within close tolerances, and this performance, which you will test in the course of your examination, depends to a large degree on the condition of the meter. However, the operation of most positive-displacement meters that are employed in vehicle-tank systems is so simple that there is no need to specify its design. The system is required, however, to be equipped with a means of preventing air and vapor from being metered, and the air eliminator, whose function and operation were described, is properly considered a component of the meter.

S.2.1. Vapor Elimination. - A metering system shall be equipped with an effective vapor or air eliminator or other automatic means to prevent the passage of vapor and air through the meter. Vent lines from the air or vapor eliminator shall be made of metal tubing or some other suitable rigid material.
(Amended 1993)

Inspect the vent line carefully. It must be made of a material, such as metal tubing, that cannot readily be crimped or manipulated in any other way to obstruct the passage of air and vapor, and it should not have any manually operated valves that could similarly impair its effectiveness if closed during operation of the system. Finally, check the entire length of the vent line for dents or breaks. One of the performance tests described in the next chapter is intended in part to assure that the air eliminator is functioning properly.

As mentioned, means must be provided for sealing the meter. Even though the adjustment mechanism used to calibrate the system is, strictly speaking, part of the indicating element, access to a mechanical adjustor, such as change gears, is accomplished simply by unbolting the register from the top of the meter. Accordingly, the meter and register should be sealed together. This is usually done by threading a wire seal through a hole drilled in one of the bolts that holds the register on top of the meter after the bolt has been put in place, but it may be done in any other way, provided that the register and meter cannot be separated without breaking the seal.

G-S.8. Provision for Sealing Electronic Adjustable Components. *- A device shall be designed with provision(s) for applying a security seal that must be broken, or for using other approved means of providing security (e.g., data change audit trail available at the time of inspection), before any change that detrimentally affects the metrological integrity of the device can be made to any electronic mechanism.*
[Nonretroactive as of January 1, 1990.]

A device may be fitted with an automatic or a semi-automatic calibration mechanism. This mechanism shall be incorporated inside the device. After sealing, neither the mechanism nor the calibration process shall facilitate fraud.
(Added 1985)(Amended 1989 and 1993)

S.2.2. Provision for Sealing. - Except on devices for metering milk, adequate provision shall be made for applying security seals in such a manner that no adjustment may be made of:

(a) any measurement element, and

(b) any adjustable element for controlling delivery rate when such rate tends to affect the accuracy of deliveries.

The adjusting mechanism shall be readily accessible for purposes of affixing a security seal.

G-UR.4.5. Security Seal. - A security seal shall be appropriately affixed to any adjustment mechanism designed to be sealed.

Access to the meter chamber is usually gained either by removing a cover plate or by separating the two hemispheres that comprise the housing. This access should also be sealed to prevent manipulation or adjustment of meter components, especially the moving segmenting elements that could affect the accuracy of the system.

PIPING

The piping, including a number of flow-regulating valves is, as you have learned, an important part of the metering system. When functioning correctly, it assures that the quantity of product registered is actually delivered and also helps prevent metering of air and vapor. Several specific requirements apply to piping.

One requirement is that check valves, installed (especially in power-operated systems) to prevent product from flowing backward, be automatic in design and not dependent on any action on the part of the operator. Equipment used exclusively for fueling aircraft is exempted from this requirement because these systems must be capable of defueling planes as well, sometimes under emergency conditions.

S.2.3. Directional Flow Valves. - Valves intended to prevent reversal of flow shall be automatic in operation. However, on equipment used exclusively for fueling aircraft, such valves may be manual in operation.

Because it is often used to deliver simultaneously to two tanks, equipment used exclusively for fueling aircraft is also exempted from the requirement that no means be provided for diverting product that has passed through the measuring chamber from the discharge line. Multiple delivery outlets can be installed in a discharge line (for example, to provide gravity-discharge service from either side of the truck).

However, if such an arrangement is used, a means must be provided to prevent delivery from more than one outlet at any one time. This is usually accomplished by means of a discharge manifold equipped with one or more multi-port valves that automatically close off all discharge outlets but the one selected for delivery.

S.3. Design of Discharge Lines and Discharge Line Valves. - (Not applicable to milk-metering systems).

S.3.1. Diversion of Measured Liquid. - Except on equipment used exclusively for fueling aircraft, no means shall be provided by which any measured liquid can be diverted from the measuring chamber of the meter or the discharge line therefrom. However, two or more delivery outlets may be installed if means is provided to insure that:

(a) liquid can flow from only one such outlet at one time, and

(b) the direction of flow for which the mechanism may be set at any time is definitely and conspicuously indicated.

As you know, a fundamental difference between gravity-discharge and power-operated systems involves the design of their discharge lines: gravity-discharge systems incorporate a "dry" hose, whereas power-operated systems incorporate a "wet" hose. Requirements for each of these types are included in Handbook 44, along with a general requirement regarding the discharge hose.

S.3.2. Pump-discharge Unit. - On a pump-discharge unit, the discharge hose shall be of the wet-hose type with a shutoff valve at its outlet end. However, a pump-discharge unit may be equipped also with a dry hose without a shutoff valve at its outlet end, but only if:

(a) the dry hose is as short as practicable, and

(b) there is incorporated in the discharge piping, immediately adjacent to the meter, effective means to insure that liquid can flow through only one of the discharge hoses at any one time and that the meter and the wet hose remain full of liquid at all times.

S.3.3. Gravity-discharge Unit. - On a gravity-discharge unit, the discharge hose or equivalent pipe shall be of the dry-hose type with no shutoff valve at its outlet end. The dry hose shall be of such stiffness and only of such length as to facilitate its drainage. The inlet end of the hose or of an equivalent outlet pipe shall be of such height as to provide for proper drainage of the hose or pipe. There shall be incorporated an automatic vacuum breaker or equivalent means to prevent siphoning and to insure the rapid and complete drainage.

S.3.4. Discharge Hose. - A discharge hose shall be adequately reinforced.

Notice that a power-operated system (pump-discharge unit) can also be equipped with a dry hose. This permits the system to be used efficiently for either type of delivery. However, in this case a multi-port valve similar to that described above must be installed to assure that the metered product can only be delivered through one hose at a time, and that the wet hose will not be drained between deliveries.

Notice also the requirement that a gravity-discharge system be equipped with a vacuum breaker to facilitate drainage. In Chapter 3, you learned that this requirement is usually met by venting the air eliminator into the intake of the discharge line.

Discharge hoses of either type must be reinforced to protect them from abrasion, punctures, and concussion during normal use. In addition, an adequately reinforced discharge hose will be less likely to become crimped, causing the flow of product to be obstructed.

Two requirements relate to the discharge valve. The first of these specifies that a valve controlling discharge can only be installed on a wet hose (such a valve on a dry hose could prevent complete drainage of the hose).

> **S.3.5. Discharge Valve.** - A discharge valve may be installed in the discharge line only if the device is of the wet-hose type, in which case such valve shall be at the discharge end of the line. Any other shutoff valve on the discharge side of the meter shall be of the automatic or semiautomatic predetermined-stop type or shall be operable only:
>
> (a) by means of a tool (but not a pin) entirely separate from the device, or
>
> (b) by mutilation of a security seal with which the valve is sealed open.

The second requirement also pertains specifically to wet-hose systems. It specifies that an antidrain valve must be installed to prevent the discharge hose from being drained between deliveries.

> **S.3.6. Antidrain Valve.** - In a wet-hose, pressure-type device, an effective antidrain valve shall be incorporated in the discharge valve or immediately adjacent thereto. The antidrain valve shall function so as to prevent the drainage of the discharge hose. However, a device used exclusively for fueling and defueling aircraft may be of the pressure type without an antidrain valve.

We discussed the function and operation of the antidrain valve in Chapter 3. In accordance with the preceding specification (S.3.5) the antidrain valve must be fully automatic. Again, equipment used

exclusively for fueling and defueling aircraft is exempt from this requirement, since an antidrain valve would effectively prevent defueling.

Your inspection of the system's piping should begin at the tank outlet or tank manifold and proceed along its length to the discharge nozzle. You should look carefully for leaks in the piping or at any of its connections. Leaks on the intake side of the meter are of special concern, since under certain conditions air may be drawn into the system through leaking piping or joints. The repair of leaks constitutes proper maintenance, which is required in the General Code (paragraph G-UR.4.1, quoted and discussed above under General Considerations).

When you reach the discharge line, you will determine whether the hose is of the correct type and properly equipped to maintain the correct condition of the hose (dry or wet) between deliveries. The effectiveness of the antidrain valve will be determined by testing, as described in the next chapter.

You should also make sure that the piping has not been installed in such a way as to facilitate fraud, which is explicitly prohibited by the General Code. This requirement is broad, and applies whether or not there is evidence that equipment is actually being used for fraudulent purposes. It therefore may cover situations which are not specifically dealt with elsewhere in Handbook 44.

> **G-S.2. Facilitation of Fraud.** - All equipment and all mechanisms and devices attached thereto or used in connection therewith shall be so constructed, assembled, and installed for use that they do not facilitate the perpetration of fraud.

Any installation of piping or valves that would permit liquid that has passed through the meter to be diverted from delivery to the buyer, either back to the vehicle tank or to some other place, would tend to facilitate fraud, as would any installation that could be used to drain a wet hose or retain product in a dry hose after the conclusion of a delivery. Finally, any installation that would tend to heat the product before it passes through the meter, either artificially (for example, by wrapping an electric heating coil around the piping, or submerging a heating element in the tank) or by permitting unnecessary exposure of piping to the sun, would also constitute facilitation of fraud. You should question the operator about any electrical wiring, switches, or connectors whose legitimate function is not apparent to you and about any valves or piping that appear unusual. Keep in mind that anyone who does use equipment for the perpetration of fraud will have made some attempt to conceal the abuse and any such abuse will not, in all likelihood, show up in the results of performance tests.

SUMMARY

The Inspection is the first of four components of an official field examination. Its purpose is to determine whether the system does or does not comply with a number of specifications and other requirements. An Inspection should be a systematic procedure for making separate determinations, as outlined in the Examination Procedure Outlines (EPO's) developed by the National Institute of Standards and Technology.